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(71) Applicant(s)
Smith International Inc
(Incorporated in USA - Delaware)
16740 East Hardy Street, Houston, Texas 77032,
United States of America

(72) Inventor(s)
Graham Mensa-Wilmot
Peter K Chan

(74) Agent and/or Address for Service
W H Beck, Greener & Co
7 Stone Buildings, Lincoln's Inn, LONDON, WC2A 3SZ,
United Kingdom

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(54) Abstract Title
Side-cutting drill bit

(57) A bit 500 for side-cutting a borehole wall comprises at least two gage pads 520 and 521 with angled gage pad portions 535 and 536 containing cutting inserts 545 and 546. A flat gage portion is provided on each pad for location of a wear resistant insert. The cutting tips of the cutters extend to the diameter of the drill bit and in cooperation result in a side cutting along the full length of the gage pad. No single gage pad includes cutters that cut the entire length of the gage pad by themselves with the effect of reducing the torque that is present on the gage pads. At least two pads are necessary to create the overlapping rotated cutting profile 510, although up to six gage pads may be used to create a contiguous overlapping cutting profile.

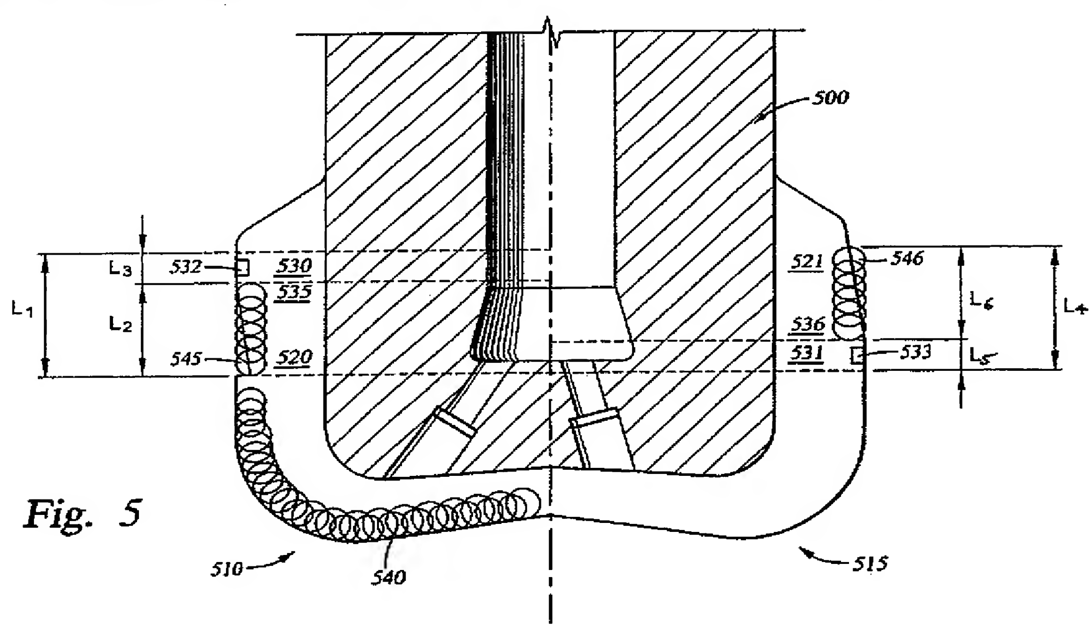

Fig. 5

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

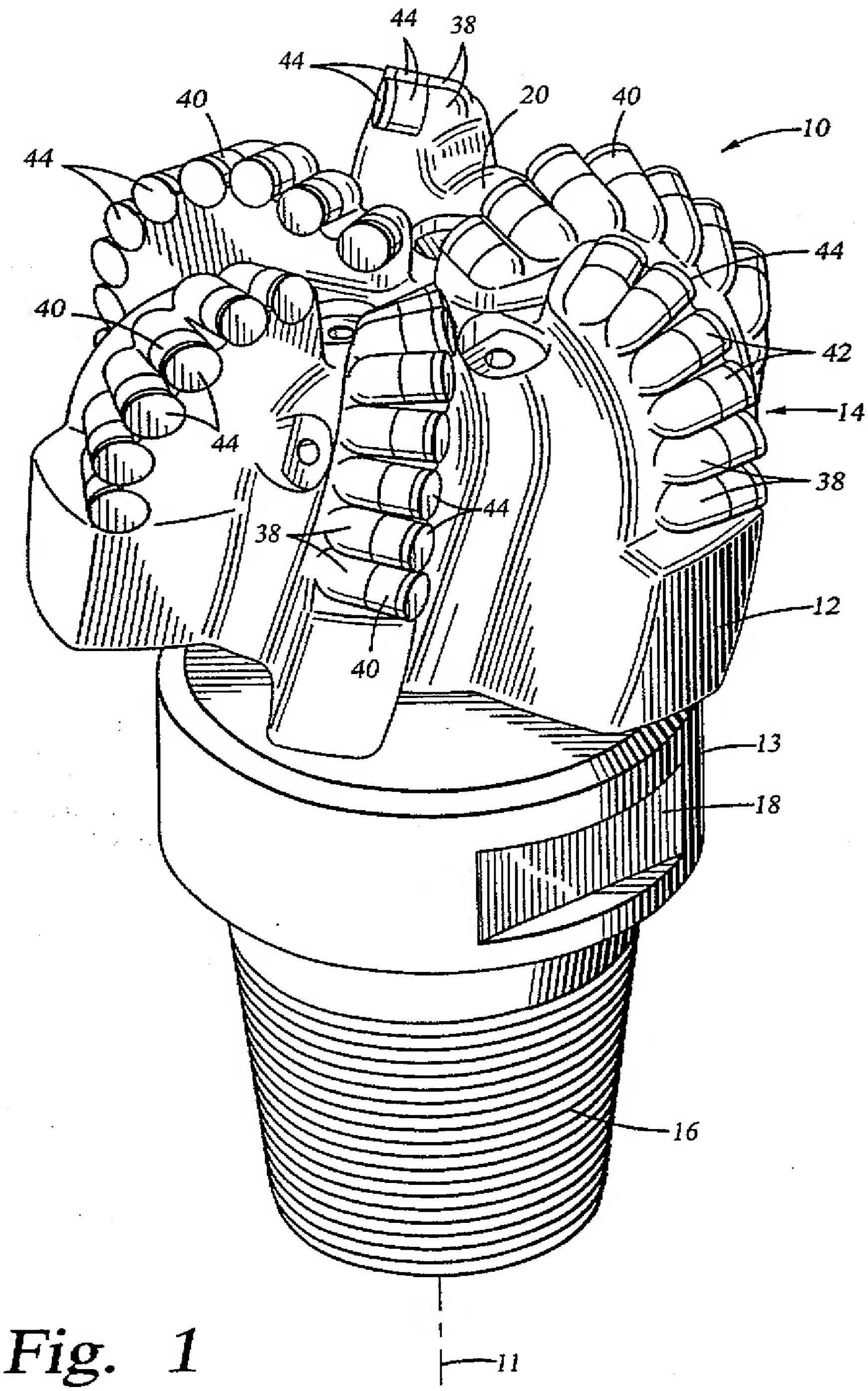


Fig. 1

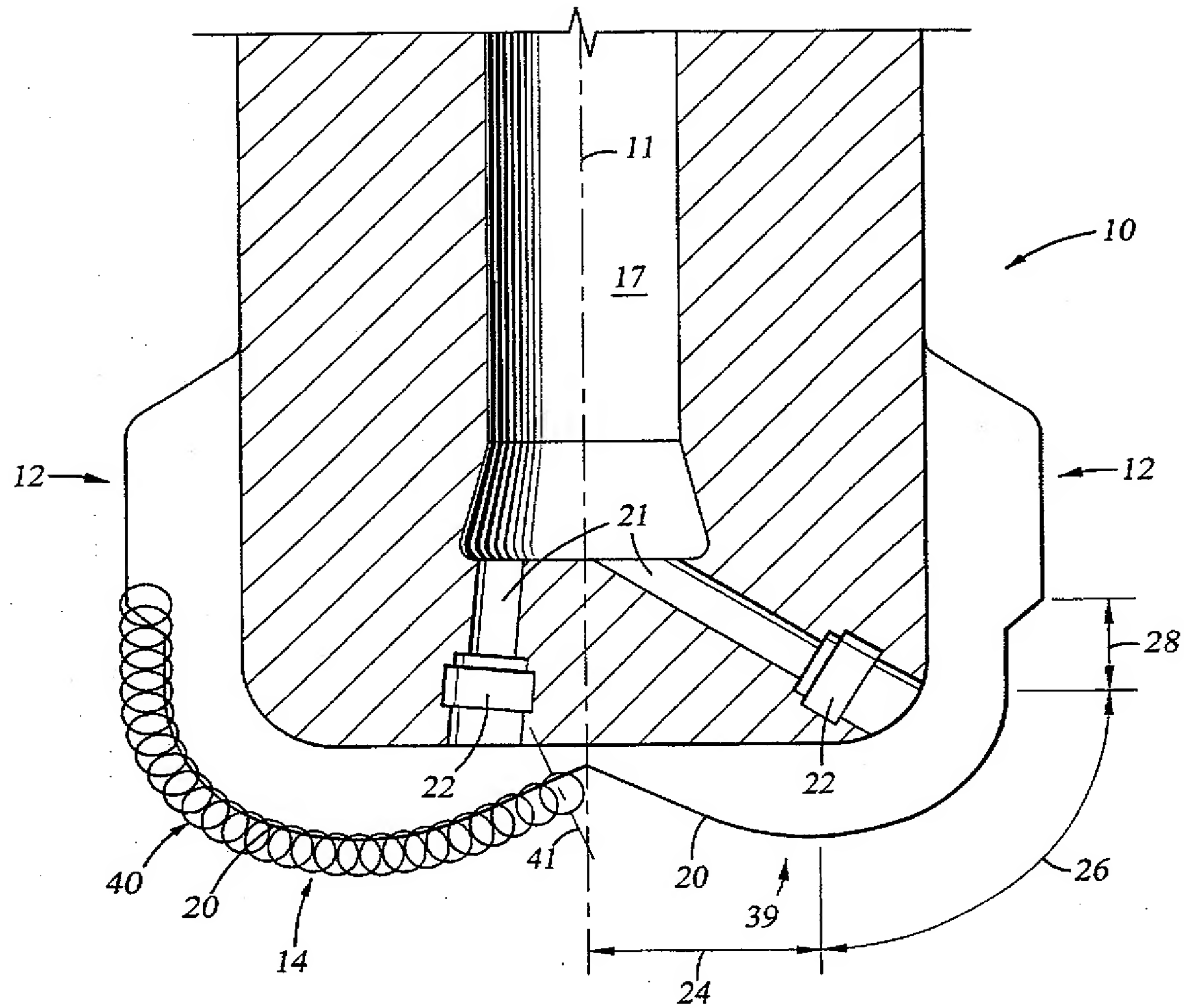


Fig. 2

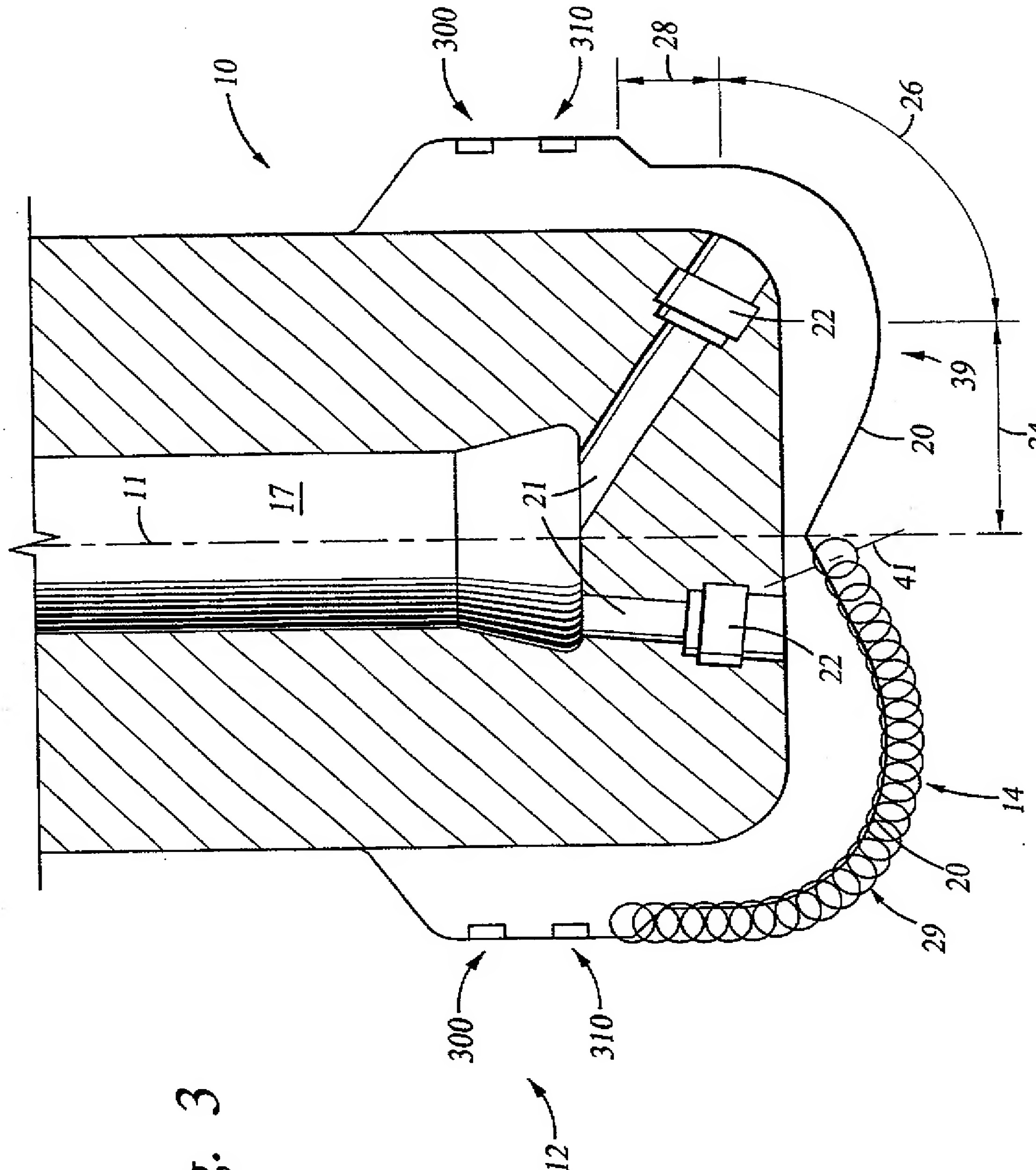


Fig. 3

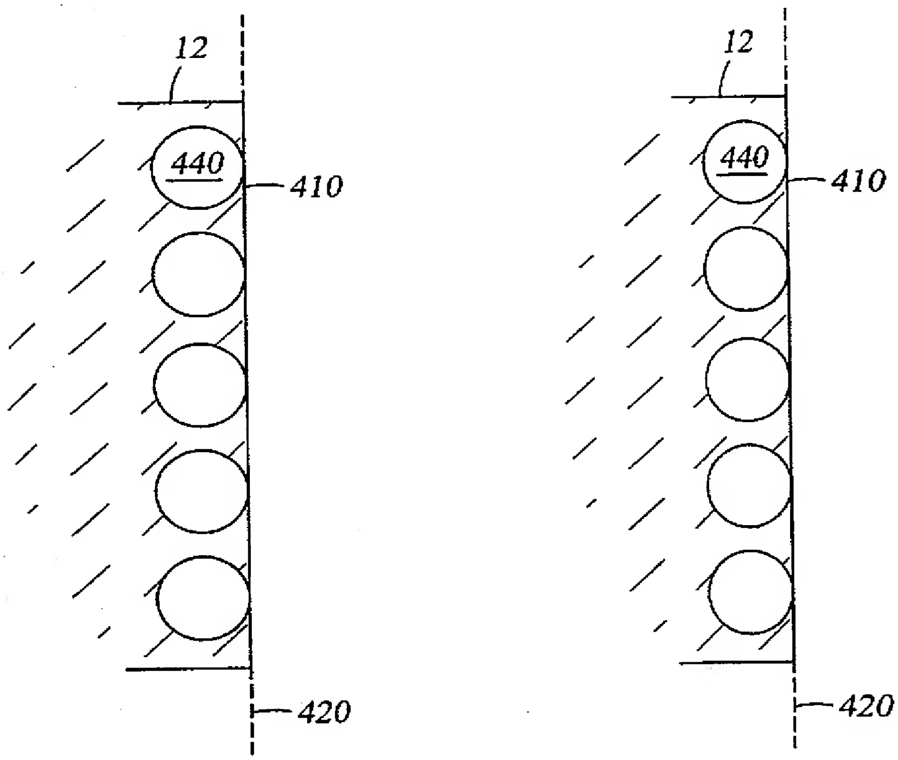


Fig. 4A

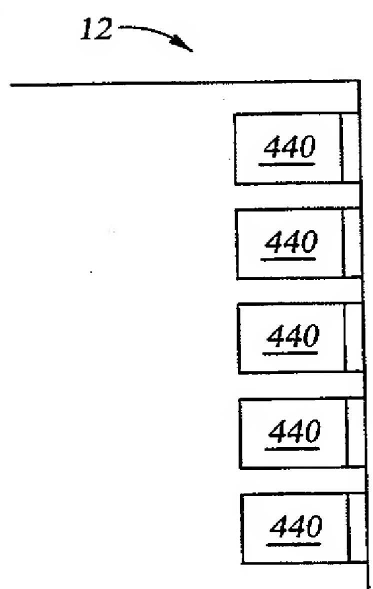


Fig. 4B

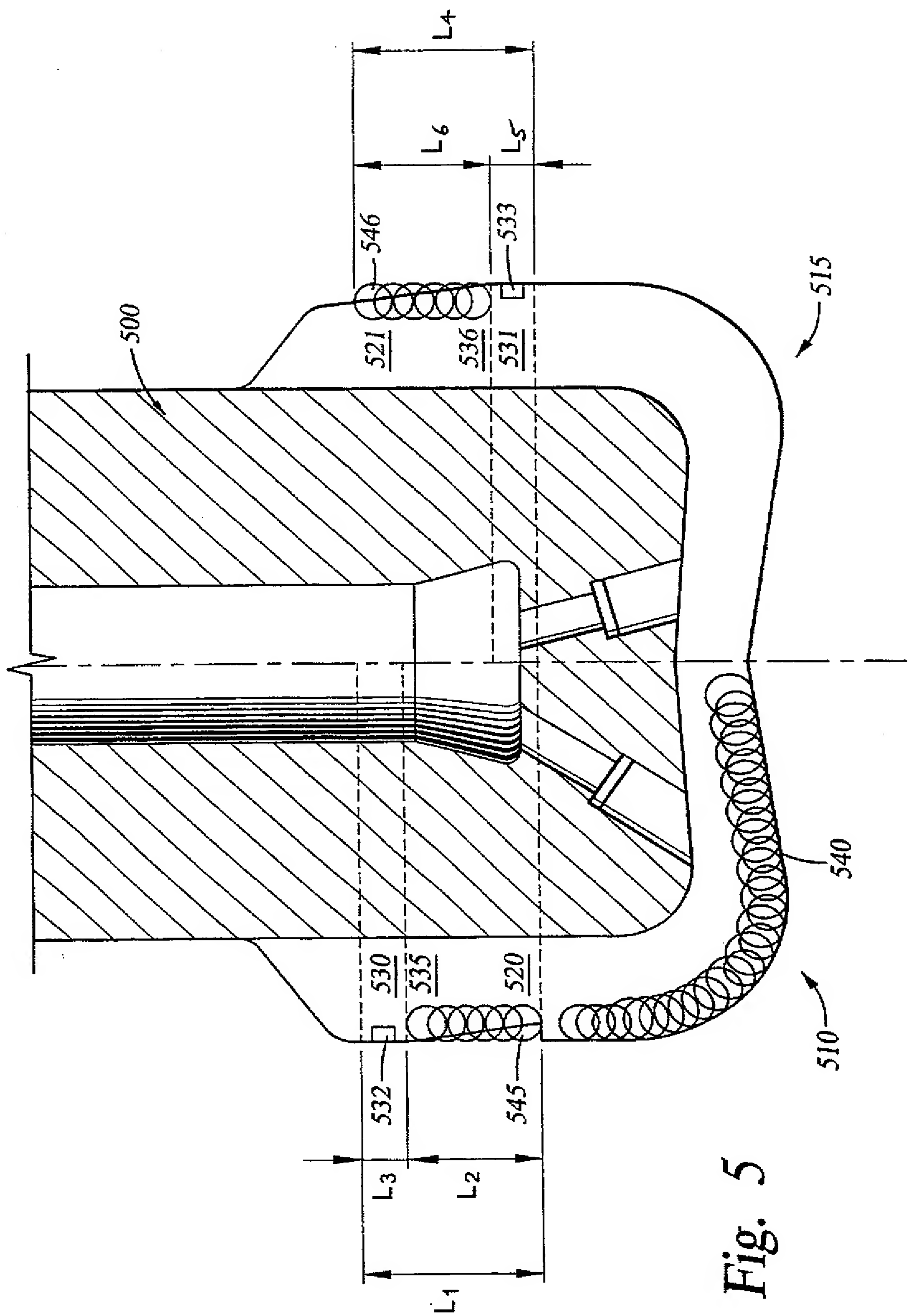

500
510
515
520
521
530
531
532
533
535
536
540
545
546
L_1
L_2
L_3
L_4
L_5
L_6

Fig. 5

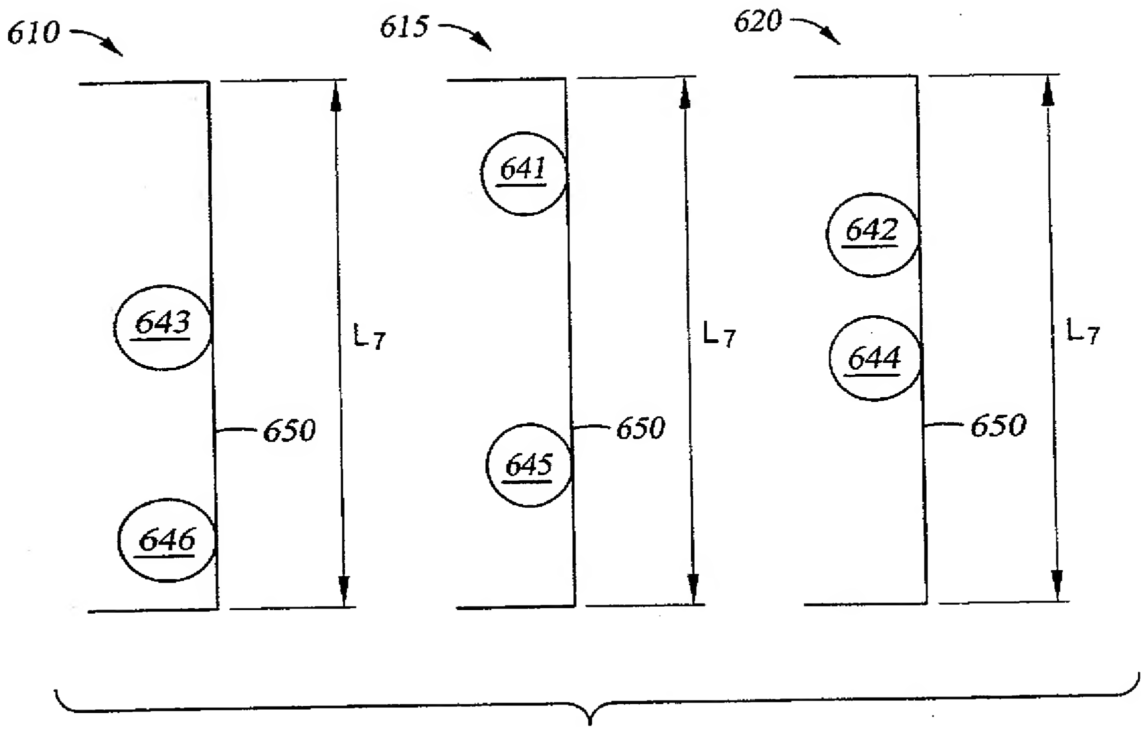
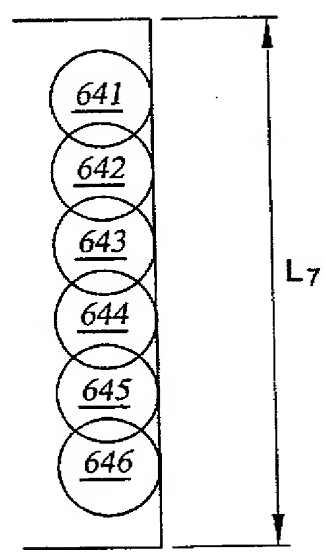
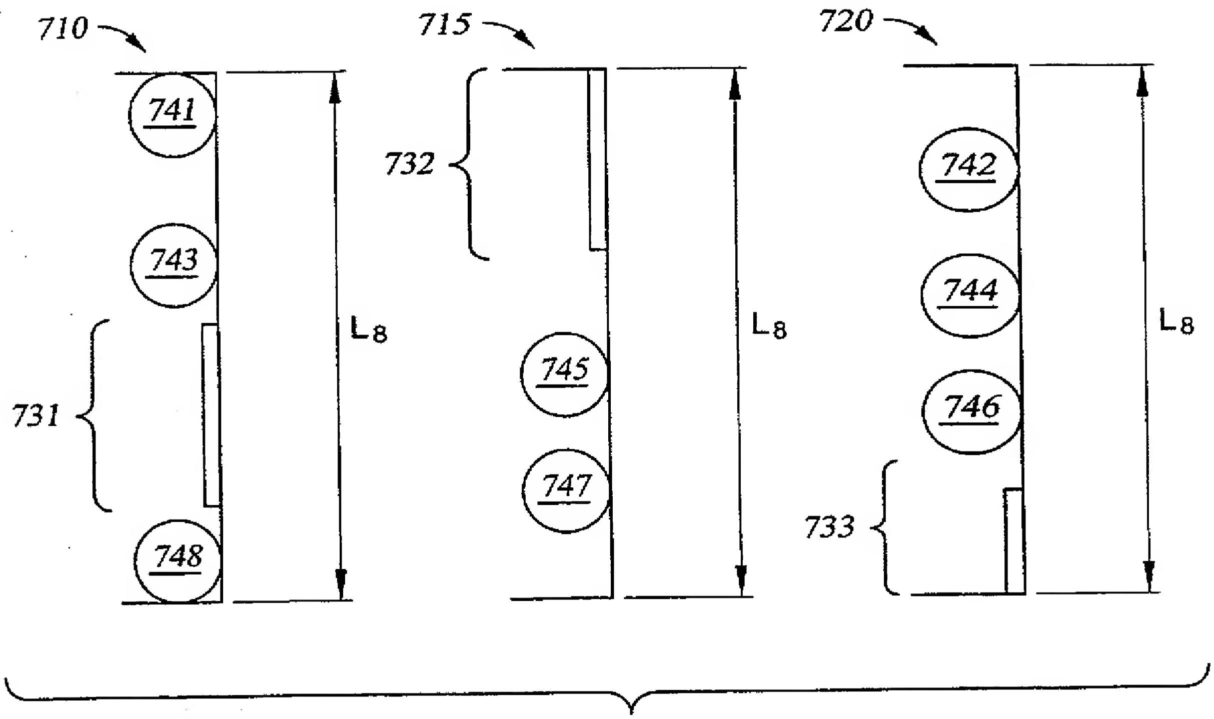

610
615
620
641
642
643
644
645
646
650
650
650
L7
L7
L7

Fig. 6A

Fig. 6B

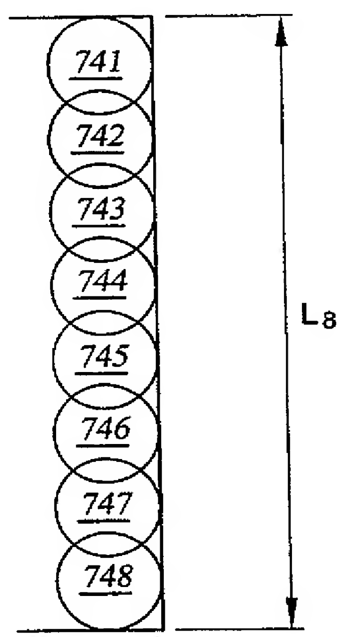

641
642
643
644
645
646
L7



710
715
720
741
743
731
748
732
745
747
742
744
746
733
L8
L8
L8

Fig. 7A

Fig. 7B



741
742
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744
745
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748
L8

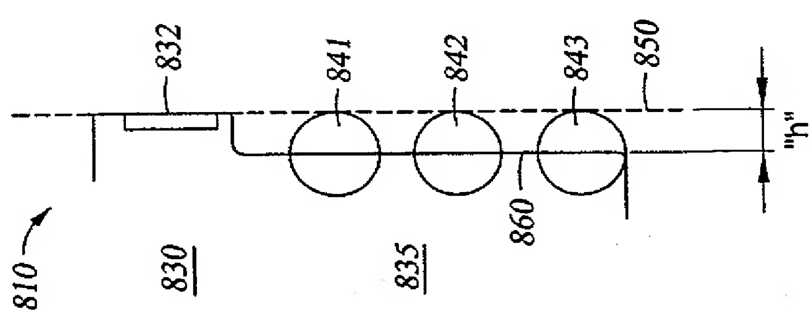

Fig. 8

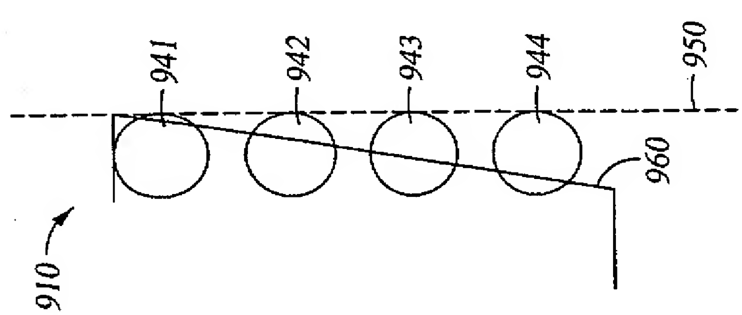

Fig. 9

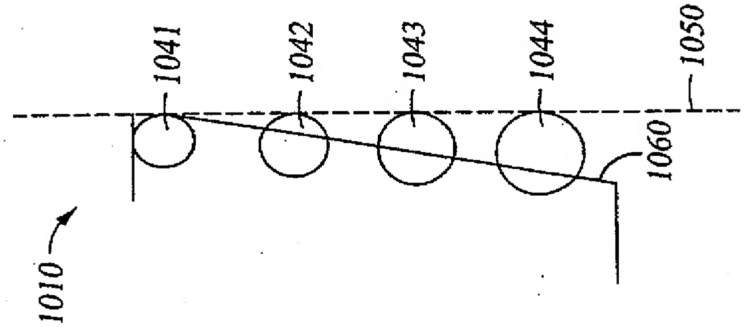

Fig. 10

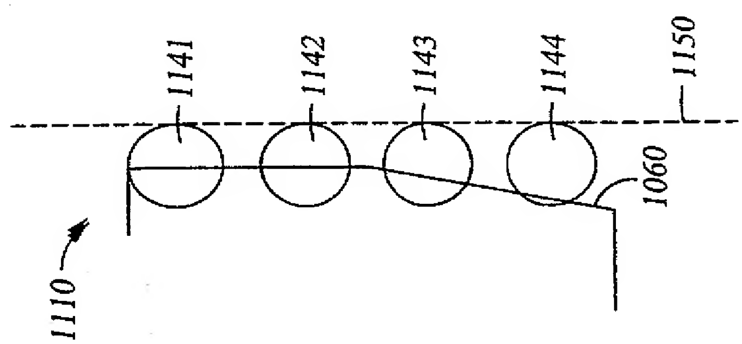

Fig. 11

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DRILL BIT

The present invention relates to a drill bit.

In drilling a borehole in the earth, such as for the recovery of hydrocarbons or for other applications, it is conventional practice to connect a drill bit on the lower end of an assembly of drill pipe sections which are connected end-to-end so as to form a "drill string". The drill string is rotated by apparatus that is positioned on a drilling platform located at the surface of the borehole. Such apparatus turns the bit and advances it downward, causing the bit to cut through the formation material by either abrasion, fracturing, or shearing action, or through a combination of all cutting methods. While the bit rotates, drilling fluid is pumped through the drill string and directed out of the drill bit through nozzles that are positioned in the bit face. The drilling fluid cools the bit and flushes cuttings away from the cutting structure and face of the bit. The drilling fluid and cuttings are forced from the bottom of the borehole to the surface through the annulus that is formed between the drill string and the borehole.

Many different types of drill bits with different rock removal mechanisms have been developed and found useful in drilling such boreholes. Such bits include diamond impregnated bits, milled tooth bits, tungsten carbide insert ("TCI") bits, polycrystalline diamond compacts ("PDC") bits, and natural diamond bits. The selection of the appropriate bit and cutting structure for a given application depends upon many factors. One of the most important of these factors is the type of formation that is to be drilled, and

more particularly, the hardness of the formation that will be encountered. Another important consideration is the range of hardnesses that will be encountered when drilling through layers of differing formation hardness.

Depending upon formation hardness, certain combinations of the above-described bit types and cutting structures will work more efficiently and effectively against the formation than others. For example, a milled tooth bit generally drills relatively quickly and effectively in soft formations, such as those typically encountered at shallow depths. By contrast, milled tooth bits are relatively ineffective in hard rock formations as may be encountered at greater depths. For drilling through such hard formations, roller cone bits having TCI cutting structures have proven to be very effective. For certain hard formations, fixed cutter bits having a natural diamond cutting structure provide the best combination of penetration rate and durability. In soft to hard formations, fixed cutter bits having a PDC cutting structure have been employed with varying degrees of success.

The cost of drilling a borehole is proportional to the length of time it takes to drill the borehole to the desired depth and location. The drilling time, in turn, is greatly affected by the number of times the drill bit must be changed in order to reach the targeted formation. This is because each time the bit is changed, the entire drill string, which may be miles or kilometres long, must be retrieved from the borehole section by section. Once the drill string has been retrieved and the new bit installed, the bit must be lowered to the bottom of the borehole on the drill string which must be reconstructed again, section by

section. As is thus obvious, this process, known as a "trip" of the drill string, requires considerable time, effort and expense. Accordingly, it is always desirable to employ drill bits that will drill faster and longer and that are usable over a wider range of differing formation hardnesses.

The length of time that a drill bit is kept in the hole before the drill string must be tripped and the bit changed depends upon a variety of factors. These factors include the bit's rate of penetration ("ROP"), its durability or ability to maintain a high or acceptable ROP, and its ability to achieve the objectives outlined by the drilling program (especially in directional applications).

In recent years, the PDC bit has become an industry standard for cutting formations of soft and medium hardnesses. The cutter elements used in such bits are formed of extremely hard materials, which sometimes include a layer of thermally stable polycrystalline ("TSP") material or polycrystalline diamond compacts ("PDC"). In the typical PDC bit, each cutter element or assembly comprises an elongate and generally cylindrical support member which is received and secured in a pocket formed in the surface of the bit body. A disk or tablet-shape, hard cutting layer of polycrystalline diamond is bonded to the exposed end of the support member, which is typically formed of tungsten carbide. Although such cutter elements historically were round in cross section and included a disk shape PDC layer forming the cutting face of the element, improvements in manufacturing techniques have made it possible to provide cutter elements having PDC layers formed in other shapes as well. A PDC bit may also include on the side of the drill

bit gage pads that, among other things, result in a reduction of the amount of vibration of the drill bit through maintenance of gage diameter. A "stable" PDC bit is desirable because excess vibration of the drill bit reduces the effectiveness and ROP of the drill bit, and consequently increases costs.

A known drill bit 10 is shown in Figure 1. Bit 10 is a fixed cutter bit, sometimes referred to as a drag bit or PDC bit, and is adapted for drilling through formations of rock to form a borehole. Bit 10 generally includes a bit body having shank 13, and threaded connection or pin 16 for connecting bit 10 to a drill string (not shown) which is employed to rotate the bit for drilling the borehole. Bit 10 has a central axis 11 and includes a cutting structure on the face 14 of the drill bit, preferably including various PDC cutter elements 40. Also shown in Figure 1 is a gage pad 12, the outer surface of which is at the diameter of the bit and establishes the bit's size. Thus, a 12″ (approx. 30cm) bit will have the gage pad at approximately 6″ (approx. 15cm) from the centre of the bit.

As best shown in Figure 2, the drill bit body 10 includes a face region 14 and a gage pad region 12 for the drill bit. The face region 14 includes a plurality of cutting elements 40 from a plurality of blades, shown overlapping in rotated profile. The action of cutters 40 drills the borehole while the drill bit body 10 rotates. Downwardly extending flow passages 21 have nozzles or ports 22 disposed at their lowermost ends. Bit 10 includes six such flow passages 21 and nozzles 22. The flow passages 21 are in fluid communication with central bore 17. Together, passages 21 and nozzles 22 serve to distribute drilling

fluids around the cutter elements 40 for flushing formation cuttings from the bottom of the borehole and away from the cutting faces 44 of cutter elements 40 when drilling.

Gage pads 12 abut against the sidewall of the borehole during drilling. The gage pads can help maintain the size of the borehole by a rubbing action when cutters on the face of the drill bit wear slightly under gage. The gage pads 12 also help stabilise the PDC drill bit against vibration. However, one problem with conventional gage pad design is excessive wear to the gage pads 12 due to their rubbing action against the borehole wall. In hard and/or abrasive formations, and also in directional applications, a method known to have helped minimise the severity of this wear problem is the placement of wear resistant materials such as diamond enhanced inserts ("DEI") and TSP elements in the gage pad, as shown in Figure 3.

Figure 3 shows another example of a prior art drill bit body 10 having a face region 14 and a gage pad region 12 for the drill bit. Each gage pad region 12 includes a first DEI 300 located directly above a second DEI 310. DEIs resist wearing away by the rubbing action of the borehole wall because they are made of a harder and more wear resistant material than that used to construct the bit body and the gage pad. Consequently, the gage pads with DEIs and TSPs continue to maintain the bit's diameter for a longer period and enhance the bit's stabilisation against vibration. However, in some applications such as in horizontal drilling or directional drilling, side cutting of the borehole wall is desirable. While this gage pad design stabilises the drill bit, it does not cut the side borehole wall.

Side cutting is a drill bit's ability to cut the sidewall of the borehole, as contrasted to the bottom of the borehole. Good side cutting action minimises torque generation by the gage pads and solves the problem of torque fluctuation or vibrational problems associated with current design technologies. As is appreciated by those of ordinary skill in the art, this is particularly important in directional drilling applications where a drill bit must achieve different trajectories as dictated by the wellbore's inclination or azimuth, instead of drilling straight ahead. Depending on the drilling program and the types of tools being used, a bit's efficiency in its application depends on its side cutting ability.

Attempts to increase the side cutting ability of a drill bit include designing a drill bit that cuts the borehole wall at the gage pad, rather than simply resisting wear with the gage pad. Figure 4A illustrates a head-on view of a pair of identical gage pads 12. The rotated profile of these gage pads 12 thus appears the same as the head-on view of a single gage pad 12. Each gage pad 12 includes a plurality of cutting elements 440. Between and beyond the gage pad cutting elements 440 of each gage pad is bit body material that creates a gage pad surface 410 that extends to gage diameter 420. Figure 4B illustrates a side view of Figure 4A showing how the cutting elements 440 are arranged on a single gage pad.

As can be appreciated, a plurality of cutters extending to gage diameter presents a cutting surface to the wall of the borehole. Such cutters are active cutting elements in the sense that they actively cut, and do not simply rub, the

sidewall of the borehole. Depending on the drilling program and the types of directional work needed, cutters 440 could be put under more challenging conditions than the cutters 14 on the bit's face. In the event of a breakage or loss of one or more of these cutting elements, little gage pad protection exists. Thus, the areas between the cutting tips of each of the cutters is filled with a hard material. This hard material forms a surface 410 at the bit diameter that attempts to maintain the bit's diameter. In the resulting design, if a gage pad cutting element breaks or becomes lost, the surface 410 of the gage pad resists wear and generally acts as a conventional gage pad. However, this design is not "aggressive" and fails to cut the borehole sidewall adequately when a significant change in the direction of the wellpath is required by the drilling program. Because side cutting is particularly important in directional drilling and rotary steerable applications, the inability to turn quickly is particularly problematic and undesirable. Further, in demanding applications such as in medium-hard, hard, or abrasive formations, the material between the cutters wears away quickly and provides inadequate gage protection.

Some increased aggressiveness of the gage cutting elements could be obtained by an increased number of similarly sized gage cutting elements along a longer gage pad. However, a longer gage pad results in a slower turning drill bit. Thus this approach is not an ideal solution to the slow turn rate problem. Further, and very significantly, a longer gage pad with more cutters tends to induce higher vibration of the drill bit during drilling because those designs increase the loading, force, and torque which, in combination with the side pushing action

needed to initiate and/or maintain the wellbore's path, would cause vibrations that become detrimental to operational efficiency. Drill bit designers have attempted to correct bit vibrational problems by altering the cutter layout on the face of the drill bit and by establishing effective force balancing methods. However, such stabilisation methods are not always effective in the highly specialised drilling applications for which a drill bit built with the inventive features disclosed herein is suited.

Therefore, a drill bit is needed that gives effective gage protection and enhances stabilisation and borehole integrity from the gage pads. The drill bit should preferably resist bit vibration, aggressively cut the borehole wall, and turn direction quickly as needed in for directional drilling programs. This drill bit should also be resistant to cutter loss or breakage, and should be suitable for use with a variety of cutter layouts on the face of the drill bit.

According to a first aspect of the present invention, there is provided a side-cutting drill bit, the drill bit comprising: a drill bit body having a face and a side; a first gage pad on said side of said drill bit body having a first plurality of cutting elements; and, a second gage pad on said side of said drill bit body having a second plurality of cutting elements; wherein said cutting elements on at least said first and second gage pads create in rotated profile only a single set of overlapping cutting elements whose periphery is contiguous.

According to a second aspect of the present invention, there is provided a drill bit, the drill bit comprising: a drill bit body having a bit diameter, said drill bit body including a first side gage pad; said first side gage pad including a first gage protection region and a first active cutting region, wherein said first gage protection region includes a straight surface that extends to approximately said bit diameter, said first gage protection region being free from active cutting elements, and wherein said first active cutting region includes at least one cutter element having a cutting tip that extends to approximately said bit diameter.

According to a third aspect of the present invention, there is provided a drill bit, the drill bit comprising: a body; and, a side gage pad area on the side of said body, said side gage pad area including a set of at least one side-disposed cutters and having a first length, said set of at least one side-disposed cutters occupying less than about 60% of said first length.

According to a fourth aspect of the present invention, there is provided a drill bit, the drill bit comprising: a body; a first side gage pad area on the side of said body, said first side gage pad area including a set of at least one side-disposed cutters and having a first length, said set of at least one side-disposed cutters occupying less than about 60% of said first length; a second side gage pad area on the side of said body, said second side gage pad area including a second set of at least one side-disposed cutters and having a second length different or the same as said first length, said second set of at least one side-disposed cutters occupying less than about 60% of said

second length; and, a third side gage pad area on the side of said body, said third side gage pad area including a third set of at least one side-disposed cutters and having a third length different or the same as said first length, said third set of at least one side-disposed cutters occupying less than about 60% of said third length; wherein said first side gage pad area, said second side gage pad area and said third side gage area form a rotated profile such that said first set, said second set and said third set combine in rotated profile to occupy at least 80% of the shortest of said first, second and third lengths and further wherein a rotated profile of any two of said first set, said second set and said third set combine in rotated profile to occupy less than about 70% of the shortest of said first, second and third lengths.

According to a fifth aspect of the present invention, there is provided a side-cutting drill bit, the drill bit comprising: a drill bit body having a face and a side; a first gage pad on said side of said drill bit body having a first plurality of cutting elements; a second gage pad on said side of said drill bit body having a second plurality of cutting elements; and, a third gage pad on said side of said drill bit body having a third plurality of cutting elements; wherein said cutting elements on at least said first, second and third gage pads create in rotated profile a single set of contiguous, overlapping cutting elements, and further wherein said cutting elements on any two of said first, second and third gage pads do not create in rotated profile only a single set of contiguous, overlapping cutting elements.

An inventive feature of the invention includes a drill bit having first and second gage pads. The cutting elements on the first and second gage pads create in rotated profile a single set of contiguous, overlapping cutting elements. A variation on this is the inclusion of a third gage pad to create the cutting profile where the cutting elements on any two of the first, second and third gage pads do not create in rotated profile a single set of contiguous, overlapping cutting elements. The invention may also include a sloped or unsloped mounting surface to which the first plurality of cutting elements is attached, at least a portion of the mounting surface being disposed away from the bit body diameter. The gage pads may also include a flat portion at the diameter of the drill bit.

Viewed differently, an inventive feature is a drill bit having a body and a side gage pad area on the body. The side gage pad area includes a set of at least one side-disposed cutters and has a first length, the set of side disposed cutters occupying less than about 60%, and preferably less than 50%, of the first length. Second and third gage pad areas may also be added, each having side disposed cutters, where the rotated profile of the side-disposed cutters on the gage pad areas occupies at least 80% of the shortest length of the two or three gage pad areas. The cutters on the three gage pad areas preferably have an exposure height, and a rubbing-action area.

The drill bit may also simply include a drill bit body having a first side gage pad, the first side gage pad having a gage protection region and an active cutting region. The gage protection region includes a straight or flat surface that extends to approximately bit diameter and being free

from active cutting elements. The active cutting region includes at least one cutter element that has a cutting tip that extends to approximately said bit diameter. The gage protection region may include a particularly abrasion resistant area with respect to the drill bit body.

Thus, the invention includes a combination of features and advantages that enable it to overcome various problems of prior drill bits and gage pads. The various characteristics described above, as well as other features, will be readily apparent to those skilled in the art upon reading the following detailed description of the preferred embodiments of the invention, and by referring to the accompanying drawings.

For a more detailed description of the preferred embodiment of the present invention, reference will now be made to the accompanying drawings, wherein:

Figure 1 is a perspective view of a prior art drill bit;

Figure 2 is a cut away view in rotated profile of a prior art drill bit;

Figure 3 is a cut away view in rotated profile of a prior art drill bit having wear-resistant inserts;

Figure 4A is a straight ahead view of a gage pad;

Figure 4B is a side view showing the arrangement of Figure 4A;

Figure 5 is a cut away view in rotated profile of an example of a drill bit according to a preferred embodiment of the invention;

Figure 6A is a straight ahead view of a set of gage pads;

Figure 6B is a view in rotated profile of the gage pads of Figure 6A;

Figure 7A is a straight ahead view of a set of gage pads;

Figure 7B is a view in rotated profile of the gage pads of Figure 7A;

Figure 8 is a straight ahead view of a gage pad with exposed cutter elements;

Figure 9 is a straight ahead view of a gage pad with cutting elements having varied exposure heights;

Figure 10 is a straight ahead view of a gage pad with variable-sized cutting elements having differing exposure heights; and,

Figure 11 is a straight ahead view of a gage pad with a portion of cutting elements having the same exposure height and a portion of cutting elements having varied exposure heights.

A drill bit 500 embodying features of the invention is shown in Figure 5. Two cutting profiles corresponding to at least four gage pads of a drill bit are shown. In the preferred embodiment, the drag drill bit includes six gage pads, although as few as two gage pads could also be used.

The drill bit 500 has first and second rotated profiles 510,515 according to the preferred embodiment. First rotated cutting profile 510 includes a gage pad 520 of length L_1. This gage pad 520 includes flat gage pad portion 530 of length L_3 substantially at gage diameter, and an angled gage pad portion 535 of length L_2. Flat gage pad portion 530 includes one or more wear resistant inserts 532. A plurality of polycrystalline diamond cutters 545 are embedded in the angled portion 535, and overlapping profiles of cutting elements 545 are shown. The cutting tips of cutters 545 extend substantially to the diameter of the drill bit. Also shown are cutter elements 540 along the face of the drill bit. Thus, at least two blades are necessary to create the illustrated overlapping profiles in first rotated cutting profile 510.

The second cutting profile 515 of Figure 5 includes a gage pad 521 of length L_4. This gage pad 521 includes flat gage pad portion 531 of length L_6 substantially at gage diameter, and an angled gage pad portion 536 of length L_5. Flat gage pad portion 531 includes one or more wear resistant inserts 533. A plurality of polycrystalline diamond cutters 546 are embedded in the angled portion 536. The cutting tips of cutters 546 extend to substantially gage diameter. In the preferred embodiment, the total length of the second gage pad 521 is L_4, and is approximately the same as the first gage pad length L_1. Similarly, lengths L_2 and

L_6 are about the same, and lengths L_3 and L_5 are about the same.

It should be understood that the flat gage pad portions are flat only with respect to the cross-sectional view of Figure 5. Along the periphery of the bit, the gage pads curve with the body of the drill bit. The one or more wear resistant inserts may be (but are not limited to) a circular PDC insert about 6-22 mm in diameter, or may constitute multiple thermally stable polycrystalline inserts of about 3mm x 5mm each.

A significant difference between the first gage pad 520 and the second gage pad 521 is the relative location of the flat portions 530 and 531 with respect to the angled portions 535 and 536. In the first cutting profile 510, the angled portion 535 lies near the face of the drill bit, with the flat portion 530 being located uphole closer to the bit shank. In the second cutting profile 515, the flat portion 536 lies near to the face of the drill bit with the angled portion 536 uphole closer to the bit shank. As shown, $L_6 \geq L_3$ and/or $L_2 \geq L_5$ so that upon rotation of the entire drill bit 500, every region along the gage pad length L_1,L_4 is touched by at least one gage pad cutter 545,546.

During side tracking, directional, and horizontal applications, it is the cooperative operation of both these cutting profiles that results in a side cutting of the full length of the gage pad. Because no single gage pad includes a set of cutters that cuts the entire length of the gage pad L_1,L_4, the torque on each gage pad is lower than it would be otherwise. This results in the elimination or drastic

minimisation of the vibrational levels that can be induced during side cutting.

Arrangements such as that shown in Figures 6A and 6B are also within the scope of the present invention. Figure 6A shows the straight-ahead cutting profile from each of three gage pads on the same bit. Although these profiles are shown side-by-side, it should be understood that upon rotation of a drill bit including this gage pad cutter arrangement, the cutting elements on these two gage pads will result in the contiguous, overlapping cutting profile of Figure 6B.

Figure 6A shows a first gage pad 610, second gage pad 615, and third gage pad 620. Each gage pad 610,615,620 is approximately of length L_7. First gage pad 610 includes cutter elements 643 and 646 substantially extending to the diameter of the bit, also called the "gage diameter". Also shown on gage pad 610 is a line 650, which may define a flat surface of a material that is generally between cutter elements 643 and 646 and that extends to the diameter of the drill bit. This hard and abrasive resistant material would respond to the borehole sidewall as a wear-resistant gage pad. In the absence of such a material between cutter elements 643 and 646 extending to the diameter of the drill bit, line 650 may simply define the diameter of the drill bit, with the surface upon which elements 643,646 are secured being elsewhere. Second gage pad 615 includes cutter elements 641 and 645 extending to about the diameter of the drill bit. Line 650 is also shown in relation to second gage pad 615. Third gage pad 620 includes cutter elements 642 and 644, and line 650 is shown in relation to third gage pad 620.

As can be seen, none of gage pads 610,615,620 has a sufficient number of cutter elements to cover the full length L_7 of the gage pad. In fact, each of the illustrated gage pads includes cutter elements that occupy less than about 60%, and preferably less than about 50%, of the gage pad length. Nevertheless, when the cutting elements from each gage pad are placed together in rotated profile, the cooperative operation of these three gage pads results in a full length cutting structure such as shown in Figure 6B (though there may still be some small portion of the gage pad that, in rotated profile, is not covered by the cutting structure). Thus, the full length cutter structure might range from 80 to 100 percent of the gage pad length with the illustrated full length cutter structure occupying about 95% of the gage pad length. Such a configuration is particularly advantageous because by placing fewer cutting elements on each gage pad, the torque on each gage pad is lowered. Lower torque on each gage pad minimises the amount of torque excitation or vibration on the drill bit.

Figures 7A and 7B illustrate yet another cooperative gage pad cutter element design within the scope of the present invention. Similar to the embodiment of Figures 6A and 6B, when the cutter elements from these three gage pads are placed together in rotated profile, a full length contiguous cutting structure results as shown in Figure 7B.

Referring now in detail to both Figures 7A and 7B, a first gage pad 710, second gage pad 715, and third gage pad 720 are each of length L_8. First gage pad 710 has cutter elements 741,743,748 extending to substantially gage diameter. First gage pad 710 also includes an area 731, all

or a portion of which may contain a particularly wear and abrasive resistant material such as DEI or TSP inserts. Second gage pad 715 includes cutter elements 745,747 extending to substantially gage diameter. Area 732 on second gage pad 715 may also contain a particularly wear and abrasive resistant material. Third gage pad 720 includes cutter elements 742,744,746, as well as area 733. As can be appreciated, the cutters from these three gage pads, in rotated profile, create a cutting profile of length L_8. Further, in rotated profile, areas 731, 732, and 733 coincide to cover a substantial length of the gage pads, and preferably coincide to cover the entire length L_8 of the gage pads. Thus, not only is each portion of the borehole sidewall corresponding to length L_8 being presented with an active cutting region, but a considerable portion of that length is also being presented with a wear-resistant region that helps to maintain gage and borehole integrity. The longer the bit maintains gage, the longer the useful life of the bit. Further, a true diameter borehole reduces operational and production costs because of the reduction of borehole drag and eases casing of the borehole. Each wear-resistant region according to this design may be enhanced by the addition of abrasion resistant inserts to extend drill bit life.

It should be noted that although each of the illustrated rotated cutting profiles extends the full length of the gage pad, a shorter cutting profile less than the full gage pad (whose length is defined by the terminal or end cutter elements in the rotated profile) yields many of the benefits of the examples shown in Figures 6 and 7, as long as the design uses the cooperative action of cutting elements from two or more gage pads, preferably three.

Figure 8 shows a gage pad 810 having a flat wear-resistant region 830 and an active cutting region 835. Flat wear-resistant region 830 may optionally include an especially wear and abrasion resistant material 832, such as one or more DEIs or TSPs. Cutting region 835 includes a plurality of cutting elements 841,842,843 whose cutting tips extend to the diameter 850 of the drill bit. Cutting elements 841,842,843 are secured to and extend a height "h" above a mounting surface 860. Exposing the cutting elements 841,842,843 on the gage pad makes the cutting structure of the gage pad more aggressive. This increased aggressiveness makes these gage pads more capable of quickly cutting the borehole sidewall. Further, the increased aggressiveness of the cutting elements may allow shortening of the gage pad itself, which makes the drill bit capable of an even higher turn rate. High turn rates are extremely beneficial in high dog-leg applications. At the same time, the flat wear-resistant region 830 on the gage pads provides the drill bit gage protection and stabilisation benefits associated with conventional non side-cutting gage pads.

The combination of the wear-resistant insert and the gage cutters on the same gage pad improves the performance of the drill bit. More specifically, by placing a wear resistant insert at one height of the gage insert, and gage pad cutters at a different height on the gage pad, an arrangement results that can yield the advantages of wear-resistant inserts with the side-cutting advantages of gage pad cutters. To fully exploit this advantage, the location of the wear resistant inserts can be at different positions along the length of the gage pad, such as shown for example in Figure 5. This results in gage pad protection as

effective as that provided by the bit shown in Figure 3 while offering improved side-cutting ability.

Referring now to Figure 9, another inventive feature angles a portion of the gage pad to expose the gage pad cutters at different heights to the surface upon which the cutters are mounted. A gage pad 910 includes a plurality of cutting elements 941-944 extending to the bit diameter 950. The gage pad 910 also includes a surface 960 that slopes away from bit diameter 950 while providing a surface upon which cutting elements 941-944 may be mounted. Similar to Figure 8, the height of each cutter is measured with respect to the surface on which the cutter is attached. This angle of surface 960 consequently means that the cutting elements 941-944 have progressively greater exposure heights, and hence become progressively more aggressive, along the length of the gage pad.

This variation in cutter exposure "height" can be helpful when drilling through formations of varying hardnesses or it may serve as an adjustable design feature for varying rates of directional changes in inclination, azimuth, or both. To ensure aggressive profiles along the entire length of the gage pad, the more exposed gage pad cutters may be at different locations along the length of different gage pads, as shown for example in Figure 5.

The particular angle selected for surface 960 is dependent on the bit size, the length of the angled portion, and the drilling program. A 7° angle away from gage diameter 950 for surface 960 might be appropriate, but a more severe angle for surface 960 may be preferable for high dog-leg applications. In fact, the angle may even change

over the length of the surface 960 if a curved surface is used instead of a straight surface. As another variation, the angled portion may instead be a cut-out trough portion or a valley "V" portion that supports the cutting elements 941-944. Further, the variation in exposure height need not extend over the entire gage pad; two or more cutting elements on the same gage pad may be of the same exposure height, such as shown in for example Figure 11.

Figure 10 shows one possible embodiment where the gage pad cutters vary in size. A gage pad 1010 includes a plurality of cutting elements 1041-1044 extending to gage diameter 1050. The gage pad 1010 also includes a surface 1060 that slopes away from gage diameter 1050 while providing a surface upon which cutting elements 1041-1044 may be mounted. Unlike the same-size cutting elements shown in Figure 9, cutting elements 1041-1044 are not all of the same diameter. The cutters may alternate in diameter, become progressively larger or smaller, or have some other pattern that varies the gage cutting element diameter.

Other variations to these embodiments may be made and still be within the scope of the invention. For example, the gage pad need only be substantially at gage or approximately at gage. "Substantially at gage" or "approximately" gage is close enough to the diameter of the drill bit to accomplish the function of a gage pad, and is envisioned to include about 20 or even 50 thousandths of an inch (approx. 0.5 or 1.3mm) below bit diameter. In addition, the wear resistant inserts may be any appropriate number, material, substance or design. For example, the described wear resistant inserts may be diamond enhanced inserts, thermally stable polycrystalline, carbide in hard

steel, or any other suitable wear-resistant material. Different size and shape cutting elements may also be employed.

While preferred embodiments of this invention have been shown and described, other modifications thereof can be made by one skilled in the art without departing from the scope of the present invention. The embodiments described herein are exemplary only and are not limiting. Many other variations and modifications of the system and apparatus are possible and are within the scope of the present invention. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims.

CLAIMS

1. A side-cutting drill bit, the drill bit comprising:

a drill bit body having a face and a side;

a first gage pad on said side of said drill bit body having a first plurality of cutting elements; and,

a second gage pad on said side of said drill bit body having a second plurality of cutting elements;

wherein said cutting elements on at least said first and second gage pads create in rotated profile only a single set of overlapping cutting elements whose periphery is contiguous.

2. A drill bit according to claim 1, wherein said drill bit body has a diameter, said first gage pad further comprising a mounting surface to which said first plurality of cutting elements is attached, at least a portion of said mounting surface being disposed away from the bit body diameter of said drill bit body, resulting in at least one of said plurality of cutting elements being exposed to aggressively cut rock formation.

3. A drill bit according to claim 2, wherein at least a portion of said mounting surface is sloped with respect to said bit body diameter.

4. A drill bit according to claim 3, wherein a majority of said mounting surface is sloped with respect to said bit body diameter.

5. A drill bit according to claim 1, wherein said first gage pad includes a first flat portion disposed at approximately the diameter of said drill bit body and a

first cutting portion that contains said first plurality of cutting elements.

6. A drill bit according to claim 5, wherein said flat portion includes a region of hard, abrasion-resistant material in comparison with said drill bit body.

7. A drill bit according to claim 5 or claim 6, wherein said second gage pad includes a second flat portion disposed at approximately the diameter of said drill bit body and a second cutting portion that contains said first plurality of cutting elements.

8. A drill bit according to claim 7, wherein in rotated profile, said first flat portion overlaps with said second cutting portion and said second cutting portion overlaps with said first flat portion.

9. A drill bit according to claim 1, wherein at least one of said cutting elements has a different exposure height from another of said cutting elements.

10. A drill bit according to claim 1, wherein said first plurality of cutting elements is mounted on said first gage pad in a generally linear arrangement between a drill bit shank and said drill bit face, said second plurality of cutting elements being mounted on said second gage pad in a linear arrangement between said drill bit shank, cutting elements from said first plurality of cutting elements becoming more exposed with respect to said first gage pad as said cutting elements from said first plurality of cutting elements become more proximate to said face of said drill bit; and, cutting elements from said second plurality of

cutting elements becoming less exposed with respect to said second gage pad as said cutting elements from said second plurality of cutting elements become more proximate to said face of said drill bit.

11. A drill bit, the drill bit comprising:

a drill bit body having a bit diameter, said drill bit body including a first side gage pad;

said first side gage pad including a first gage protection region and a first active cutting region, wherein said first gage protection region includes a straight surface that extends to approximately said bit diameter, said first gage protection region being free from active cutting elements, and wherein said first active cutting region includes at least one cutter element having a cutting tip that extends to approximately said bit diameter.

12. A drill bit according to claim 11, wherein said first gage protection region further comprises a particularly abrasion resistant area with respect to said drill bit body.

13. A drill bit according to claim 11 or claim 12, wherein said drill bit body includes a second side gage pad, said second side gage pad including a second gage protection region and a second active cutting region, wherein said second gage protection region includes a straight surface that extends to approximately said bit diameter, said second gage protection region being free from active cutting elements, and further wherein said second active cutting region includes at least one cutter element having a cutting tip that extends to approximately said bit diameter, said second gage protection region being closer to said bit face than said first gage protection region is.

14. A drill bit according to claim 13, wherein said first gage protection region has a first gage protection midpoint midway between said first gage protection region, said second gage pad protection region has a second gage protection midpoint midway between said second gage protection region, said first gage protection midpoint and said second gage protection midpoint being at different locations when said first and second gage pads are placed in rotated profile.

15. A drill bit according to any of claims 11 to 14, wherein said first active cutting region includes exposed active cutting elements, said first active cutting region being free from a straight surface between any two of said active cutting elements that extend to substantially bit diameter.

16. A drill bit according to claim 11, wherein said active cutting elements are mounted on a surface, said surface extending to a location below approximately said bit diameter.

17. A drill bit according to claim 16, wherein said surface is sloped.

18. A drill bit according to claim 17, wherein said sloped surface is a straight slope.

19. A drill bit according to claim 11, further comprising a second gage pad and a third gage pad, said second gage pad including a second active cutting region with active cutting elements and said third gage pad including a third active

cutting region with active cutting elements, said first, second and third active cutting regions overlapping in rotated profile such that said active cutting elements from said first gage pad and said active cutting elements from said second gage pad overlap to form at least two sets of non-touching cutting element profiles.

20. A drill bit according to claim 13, wherein said first active cutting region overlaps but is not co-extensive with said second active cutting region in rotated profile.

21. A drill bit, the drill bit comprising:

a body; and,

a side gage pad area on the side of said body, said side gage pad area including a set of at least one side-disposed cutters and having a first length, said set of at least one side-disposed cutters occupying less than about 60% of said first length.

22. A drill bit according to claim 20, wherein said set of at least one side-disposed cutters occupies less than about 50% of said first length.

23. A drill bit according to claim 21 or claim 22, further comprising:

a second side gage pad area on the side of said body, said second side gage pad area including a second set of at least one side-disposed cutters and having a second length different or the same as said first length, said second set of at least one side-disposed cutters occupying less than about 60% of said second length;

wherein said first side gage pad area and said second side gage pad area form a rotated profile such that said first set and said second set combine in rotated profile to occupy at least 80% of the shortest of said first and second lengths.

24. A drill bit according to claim 23, wherein said second set of at least one side-disposed cutters occupies less than about 50% of said first length.

25. A drill bit according to claim 24, wherein said rotated profile occupies at least 90% of the shortest of said first, second and third lengths.

26. A drill bit according to any of claims 21 to 25, wherein each of said side-disposed cutters has a cutting tip; at least one of said side-disposed cutters being exposed to create a height between said cutting tip of said at least one of said side-disposed cutters that is exposed and a surface upon which said at least one of said side-disposed cutters that is exposed is attached.

27. A drill bit according to claim 26, wherein a plurality of said side-disposed cutters are exposed at differing heights.

28. A drill bit according to claim 21, wherein said side gage pad includes a rubbing action portion extending to approximately gage diameter.

29. A drill bit according to any of claims 21 to 28, wherein said first, second, and third gage pads include first, second, and third respective rubbing-action portions.

30. A drill bit according to claim 29, wherein said first, second and third respective rubbing-action portions combine in rotated profile to occupy at least about 80% of the shortest of said first, second, and third lengths.

31. A drill bit, the drill bit comprising:

a body;

a first side gage pad area on the side of said body, said first side gage pad area including a set of at least one side-disposed cutters and having a first length, said set of at least one side-disposed cutters occupying less than about 60% of said first length;

a second side gage pad area on the side of said body, said second side gage pad area including a second set of at least one side-disposed cutters and having a second length different or the same as said first length, said second set of at least one side-disposed cutters occupying less than about 60% of said second length; and,

a third side gage pad area on the side of said body, said third side gage pad area including a third set of at least one side-disposed cutters and having a third length different or the same as said first length, said third set of at least one side-disposed cutters occupying less than about 60% of said third length;

wherein said first side gage pad area, said second side gage pad area and said third side gage area form a rotated profile such that said first set, said second set and said third set combine in rotated profile to occupy at least 80% of the shortest of said first, second and third lengths and

further wherein a rotated profile of any two of said first set, said second set and said third set combine in rotated profile to occupy less than about 70% of the shortest of said first, second and third lengths.

32. A side-cutting drill bit, the drill bit comprising:

a drill bit body having a face and a side;

a first gage pad on said side of said drill bit body having a first plurality of cutting elements;

a second gage pad on said side of said drill bit body having a second plurality of cutting elements; and,

a third gage pad on said side of said drill bit body having a third plurality of cutting elements;

wherein said cutting elements on at least said first, second and third gage pads create in rotated profile a single set of contiguous, overlapping cutting elements, and further wherein said cutting elements on any two of said first, second and third gage pads do not create in rotated profile only a single set of contiguous, overlapping cutting elements.

33. A drill bit substantially in accordance with any of the examples as hereinbefore described with reference to and as illustrated by Figures 5 to 11 the accompanying drawings.

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Application No: GB 0019355.7
Claims searched: 1-10,31,32

Examiner: Ian Blackmore
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Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): E1F FFP, FFR, FGA, FGC

Int Cl (Ed.7): E21B

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2328964 A	(BAKER HUGHES INCORPORATED) see figure 1 & 1A	-
A	GB 2301852 A	(SMITH INTERNATIONAL)	-
A	EP 0164297 A2	(HUGHES TOOL COMPANY)	-
A	EP 0127077 A2	(NORTON) see figures 5a & 6b	-

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